Synergistic use of MODIS and MISR to quantify the uncertainties in cloud microphysical properties over the globe

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Question

Using the standard satellite VIS-SWIR technique for retrieving optical depth of water clouds over ocean, what fraction of pixels with retrieved optical depths have uncertainties of better than 20%?

a) > 90%

b) 70 to 90%

c) 50 to 70%

d) 30 to 50%

e) < 30%

Motivation

- The retrieval of cloud microphysical properties (e.g., optical depth, τ, and effective radius, r_e) over the globe are now routine using visible and near-IR satellite imaging systems (e.g., MODIS, AVHRR).

- These datasets are used extensively in many scientific studies of global water and energy cycles.

- The conclusions of these studies are hampered by an incomplete assessment of the uncertainties in the retrieved microphysical properties, where the uncertainties are likely dependent on the cloud optical properties and their spatial distribution, the sun-view geometry, etc.

How do we know the pixel-level uncertainty in τ and r_e?

1) Uncertainty range from 3-D radiative transfer modeling

2) Compare with ground-based estimates (e.g., from ARM)

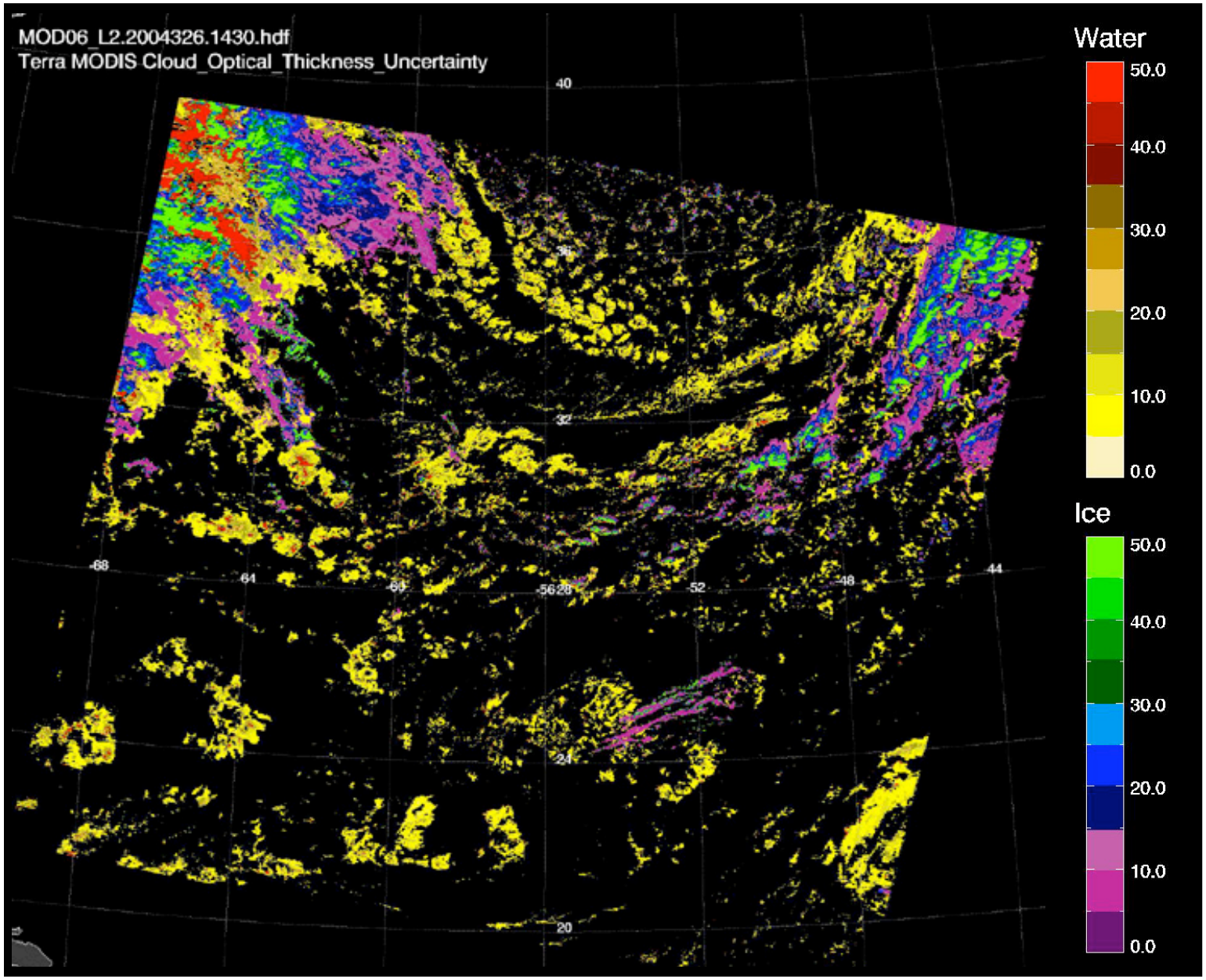
These approaches cannot give the global distribution of the uncertainties.

3) Uncertainty estimates from retrieval sensitivity to changes in cloud-top reflectance, etc., as in MODIS Collection 5.

This is a great start, but only describes part of the uncertainty… not all contributing factors (e.g., cloud vertical and horizontal heterogeneity) are accounted for.

Optical Thickness Retrieval Relative Uncertainty (%)

(collection 5 preliminary)



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2) Compare with ground-based estimates (e.g., from ARM)

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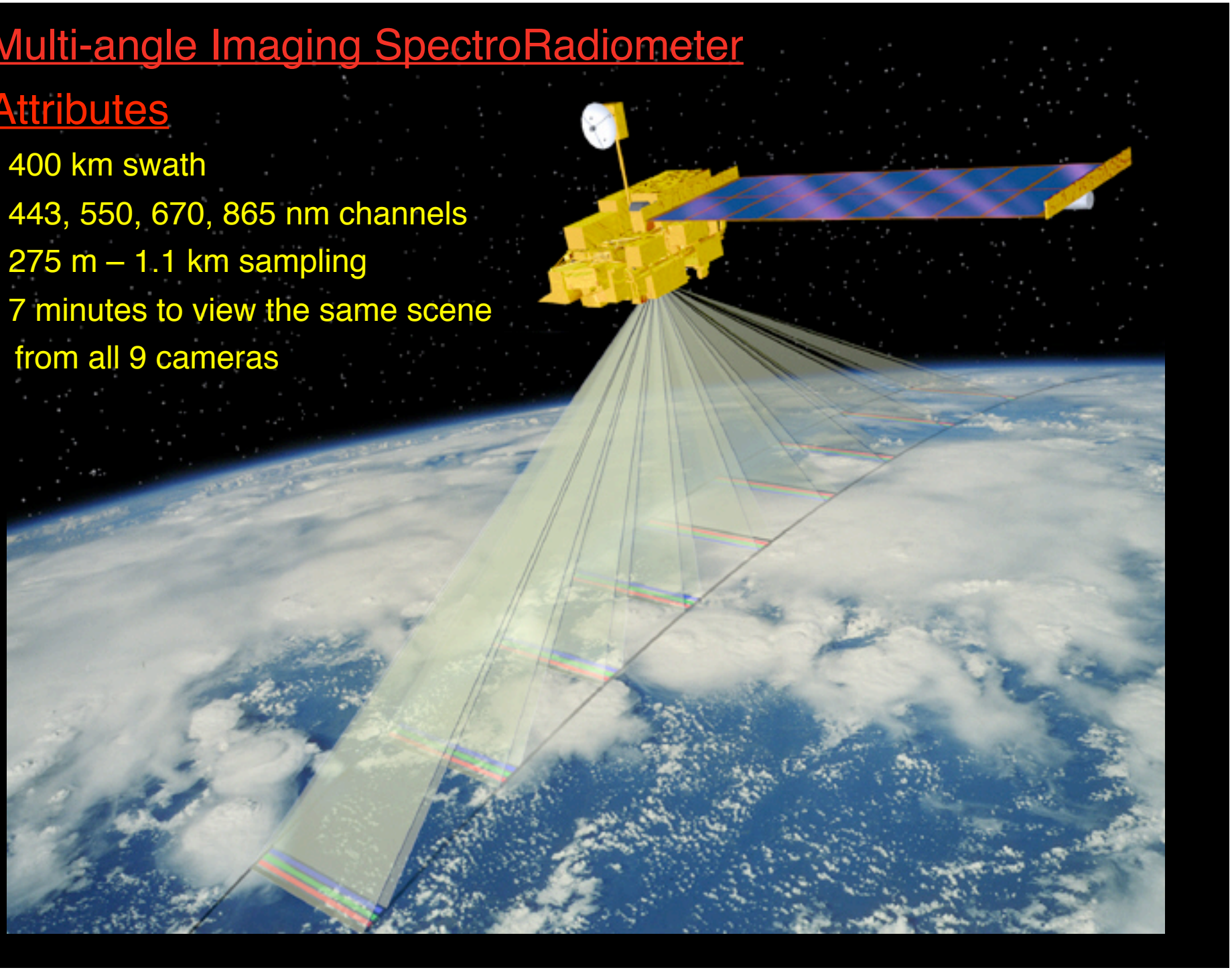
Multi-angle Imaging SpectroRadiometer

Attributes

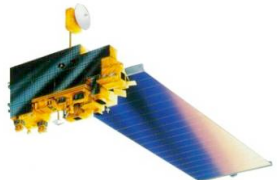
- 400 km swath
- 443, 550, 670, 865 nm channels
- 275 m – 1.1 km sampling
- 7 minutes to view the same scene from all 9 cameras



Approach #1

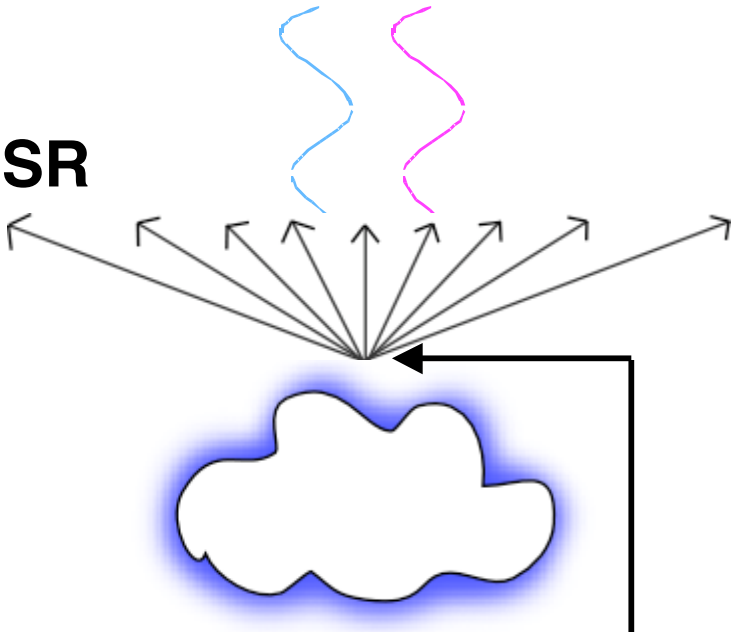
MODIS → τ, r_e

$$E_1 = \frac{1}{N}\sum_{i=1}^{N}\frac{\left|R_{MISR}(i) - R_{sim}(i)\right|}{R_{MISR}(i)}$$

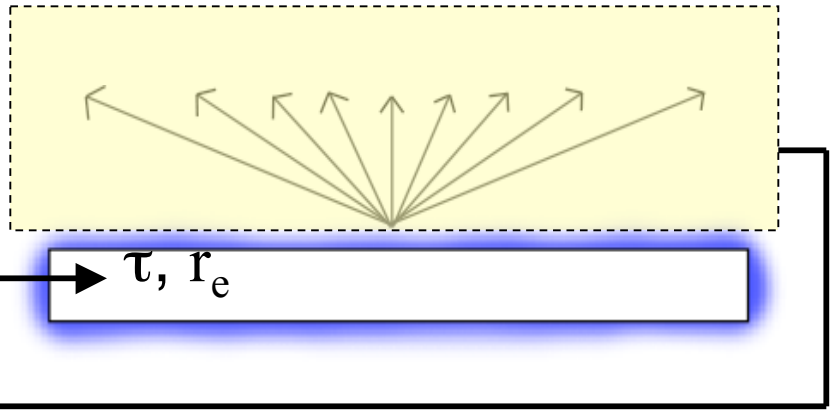


VIS SWIR

MISR



Same 1-D Radiative Transfer used in MODIS retrieval

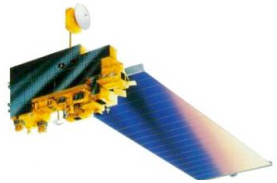


Surface

Surface

Approach #2

MODIS → r_e

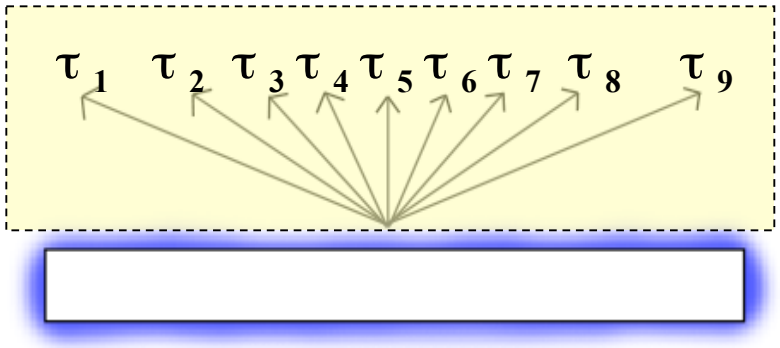


VIS SWIR

MISR

$$E_2 = \frac{\sigma(\tau)}{\bar{\tau}}$$

MODIS based τ - LUT



Surface

Surface

Can also use r_e, LWP or albedo

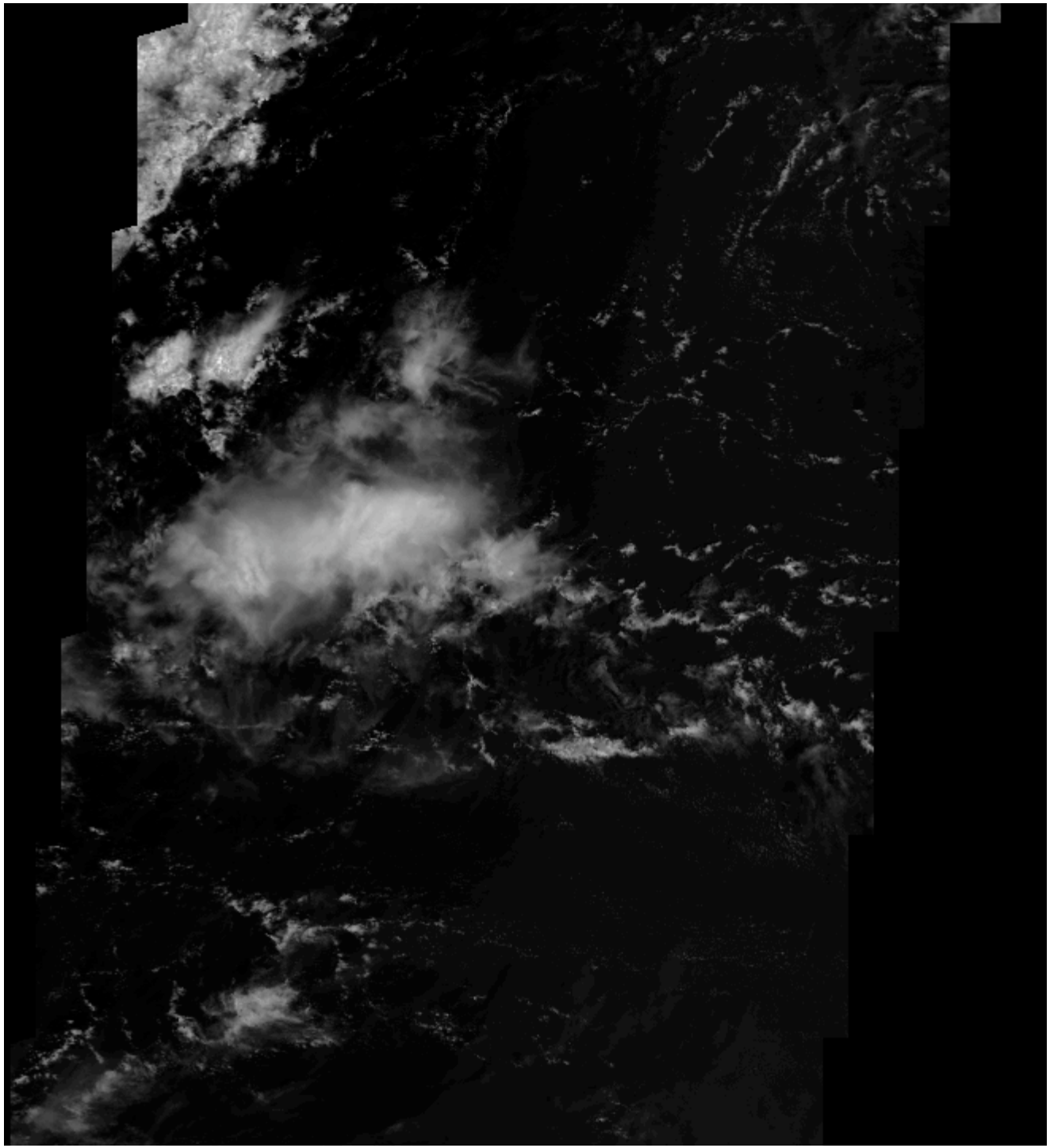
Data Fusion Requires…

1) reprojecting the MODIS data onto the MISR grid with a Nearest Neighbor technique;

2) registering the same cloud element within the 9 MISR images using the MISR M2 and M3 stereo matching techniques;

3) the reprojection is verified by applying the matching techniques between the MODIS and MISR-nadir images;

4) other radiometric considerations not described here.

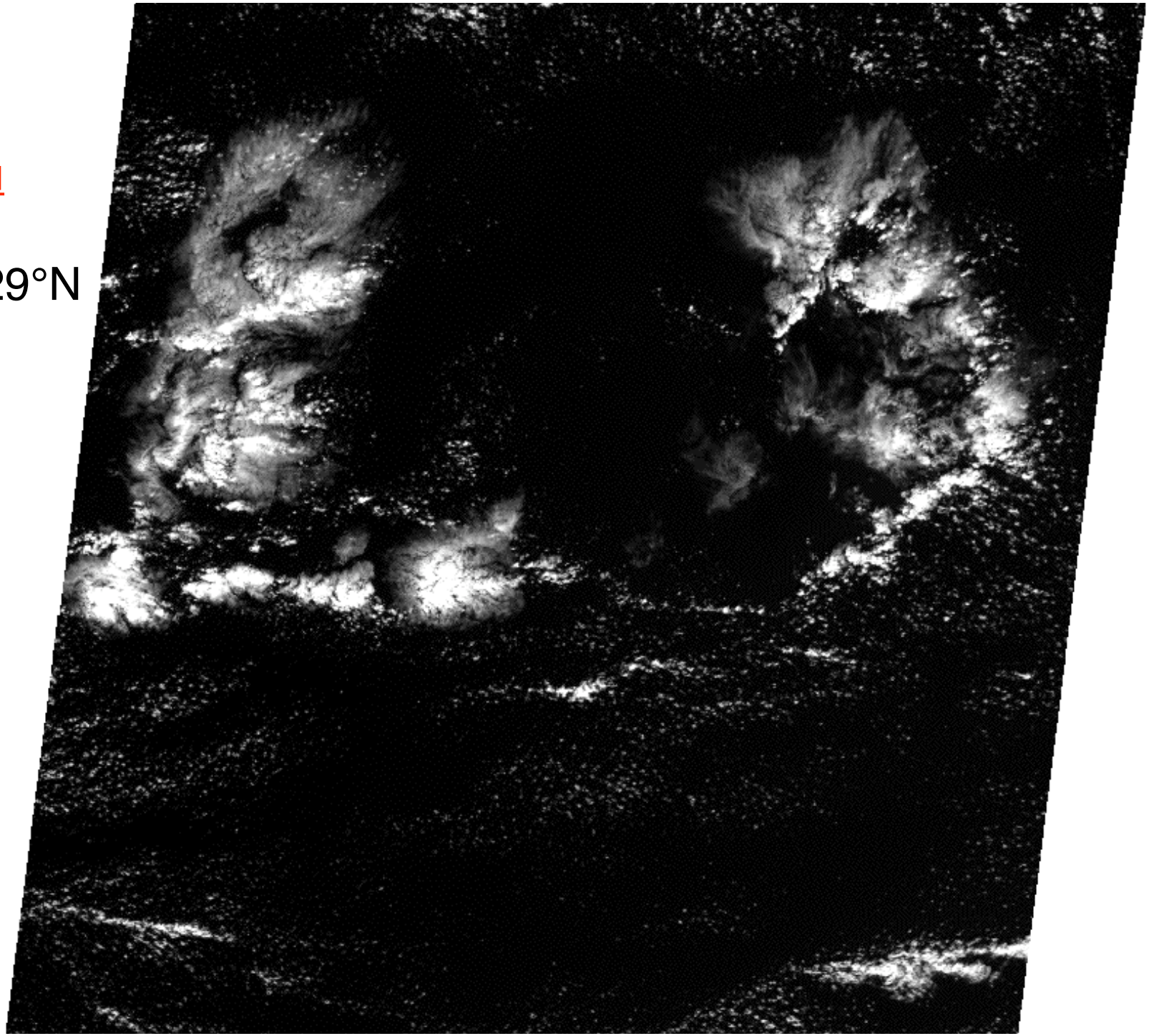


Trade Cu

Path 233

12°N to 29°N

7 days

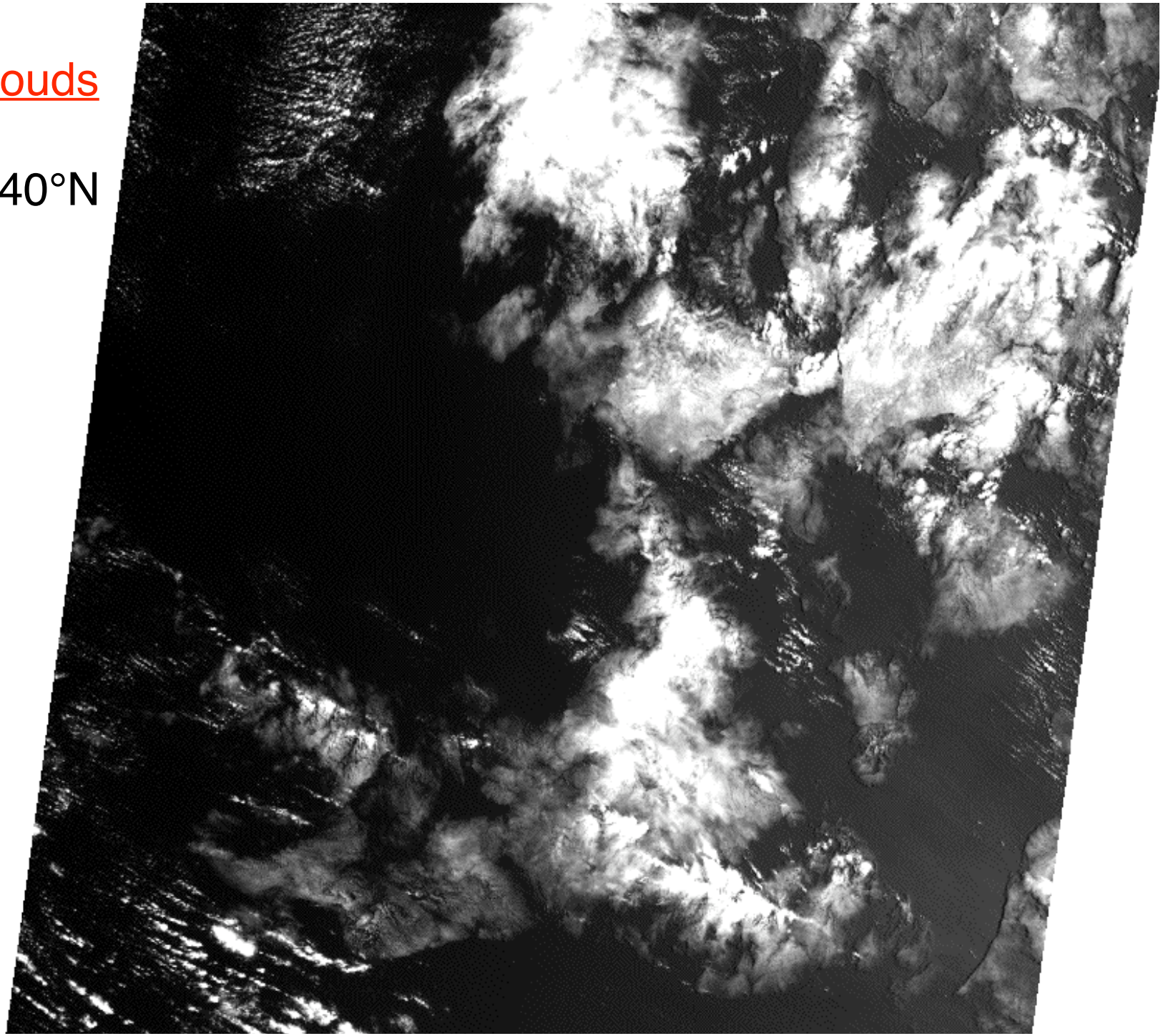


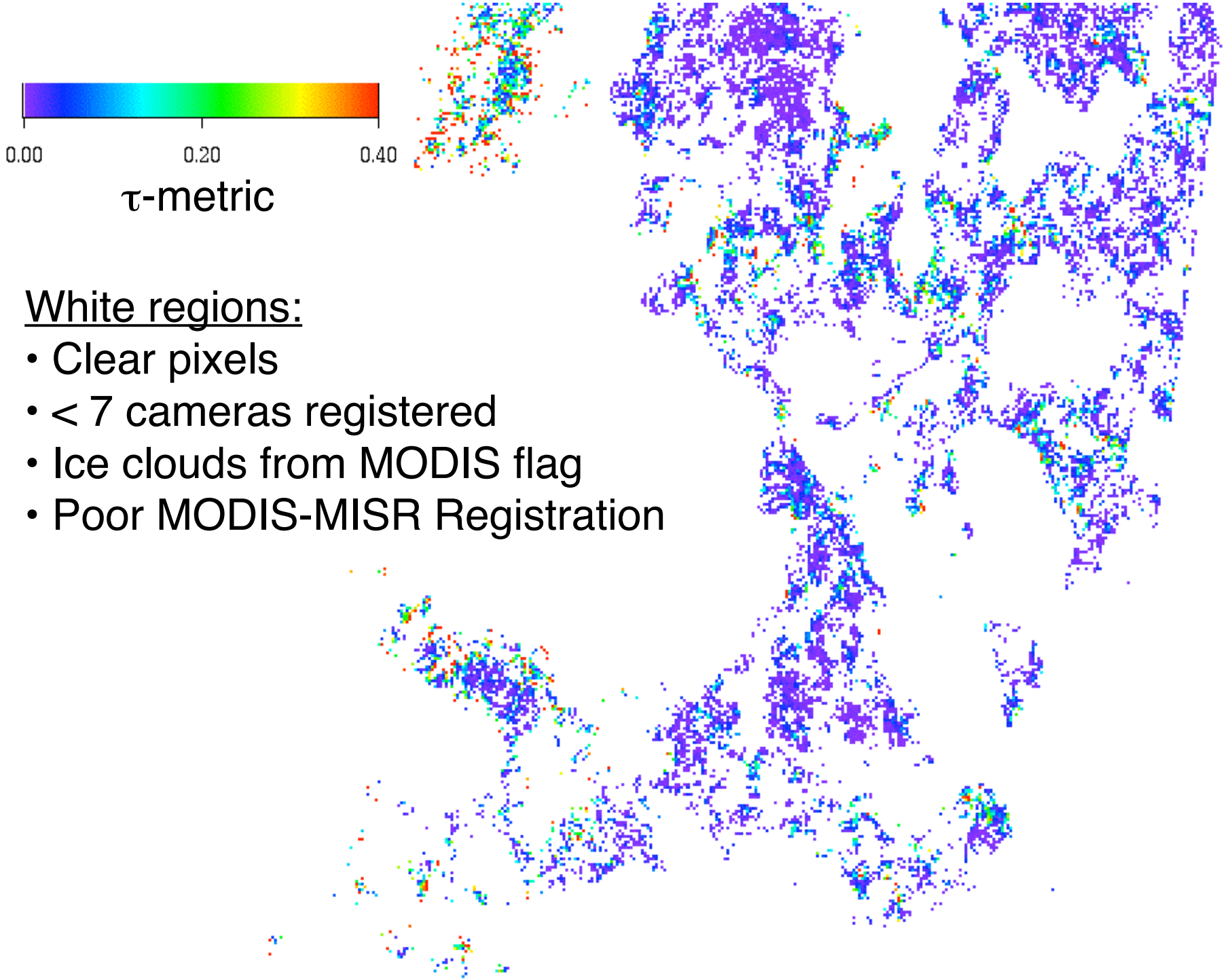
Mixed clouds

Path 48

20°N to 40°N

6 days

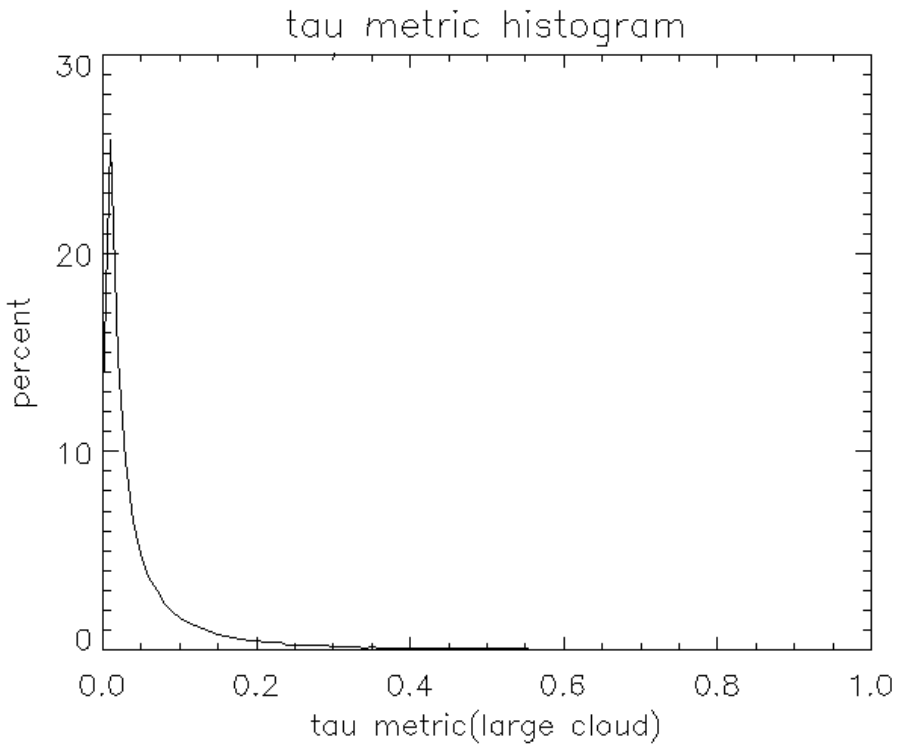


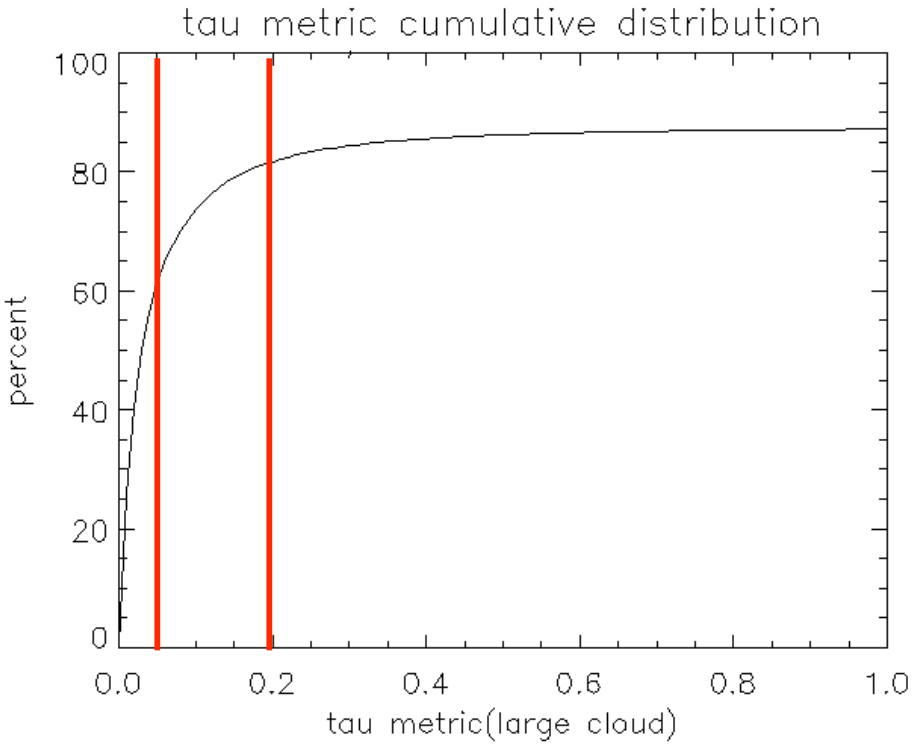


White regions:

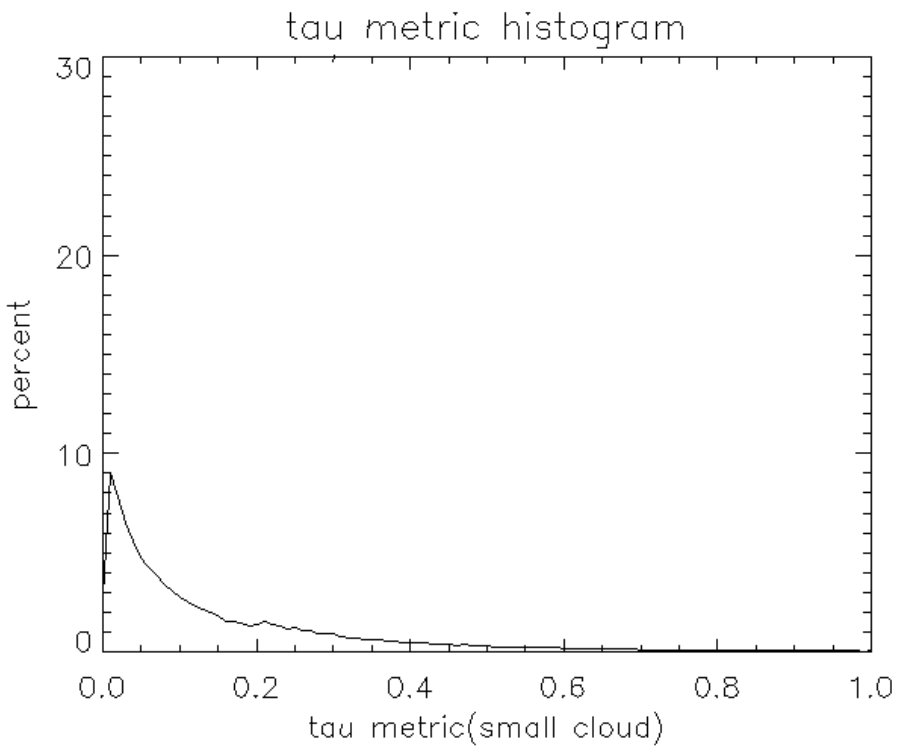
- Clear pixels
- < 7 cameras registered
- Ice clouds from MODIS flag
- Poor MODIS-MISR Registration

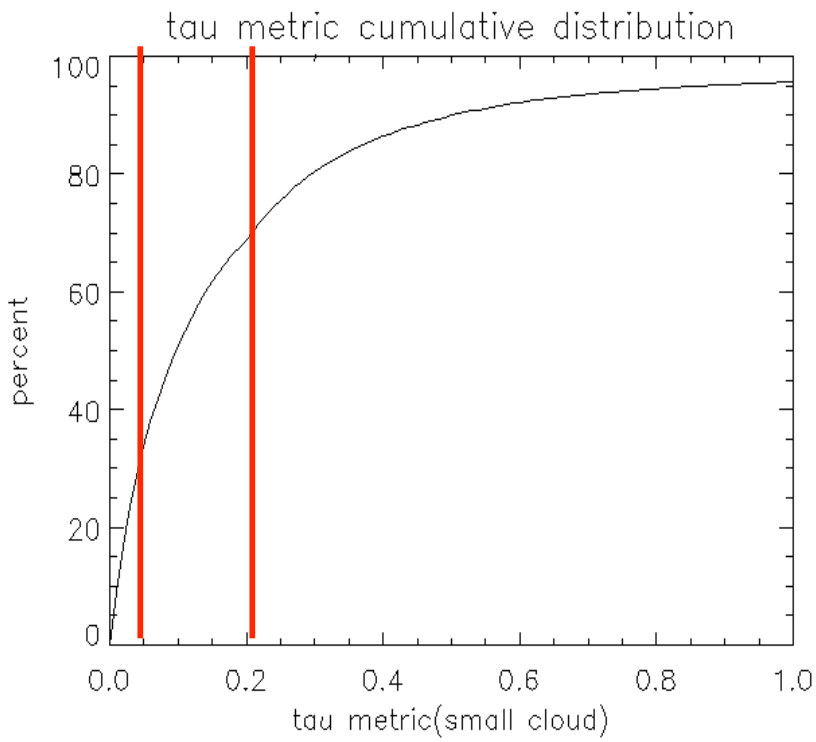
τ-metric: Path 48 (mixed clouds)



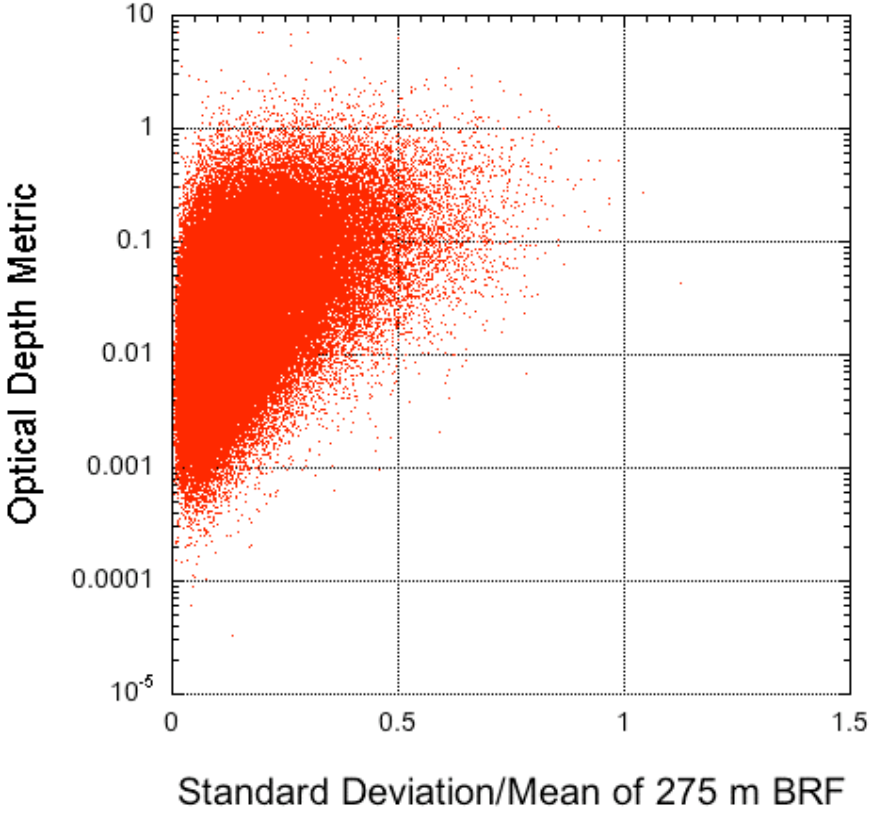


τ-metric: Path 233 (trade cumuli)

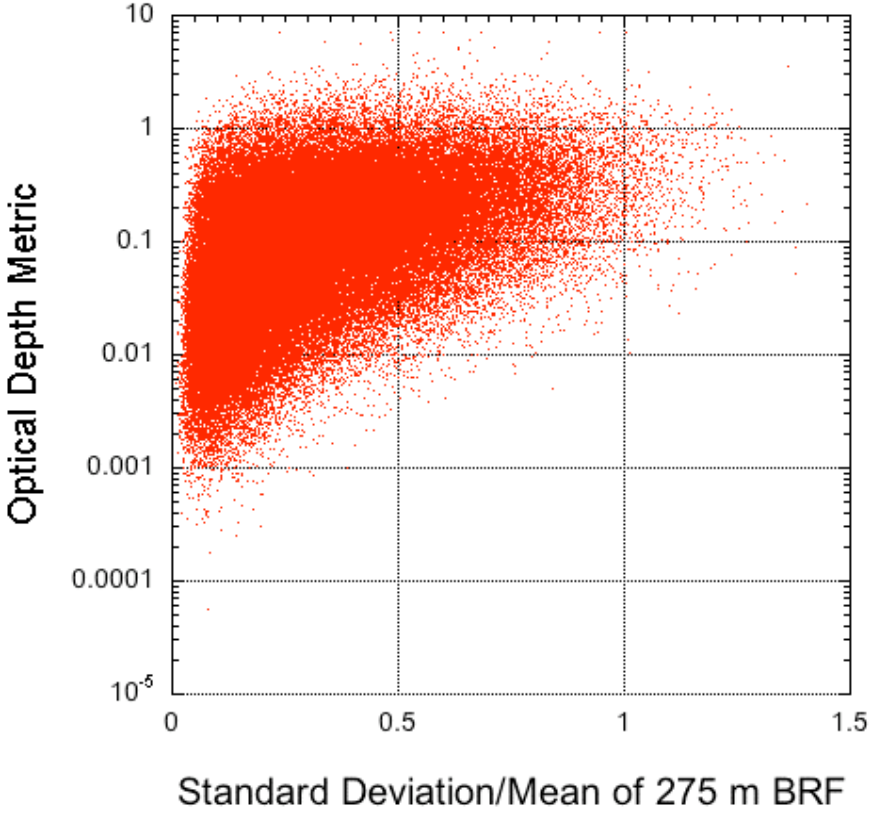




Path 48 Mixed Clouds



Path 233 Trade Cumulus

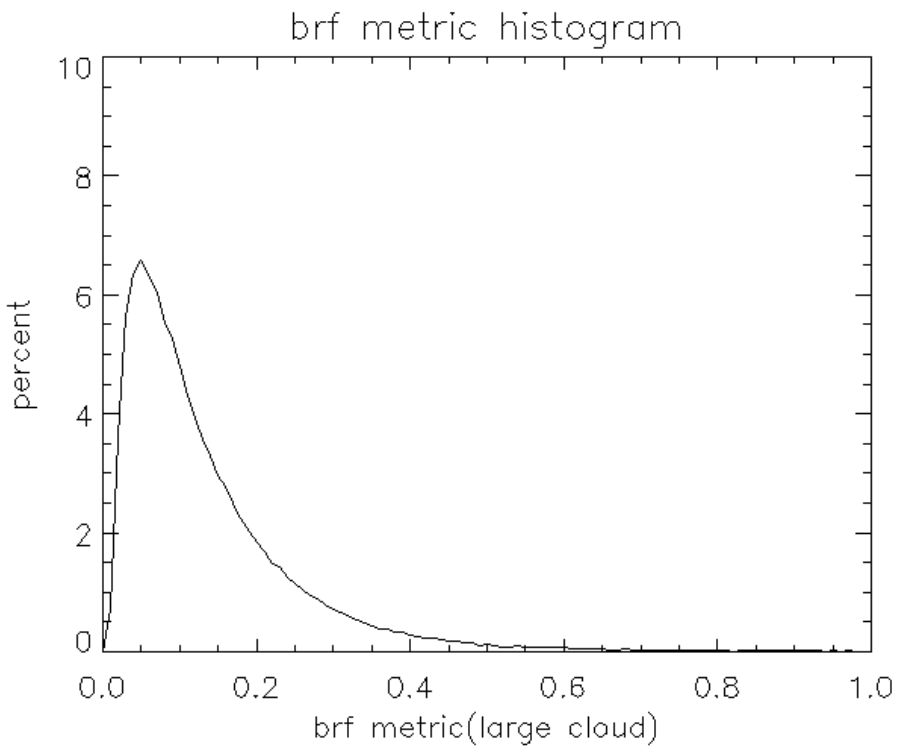


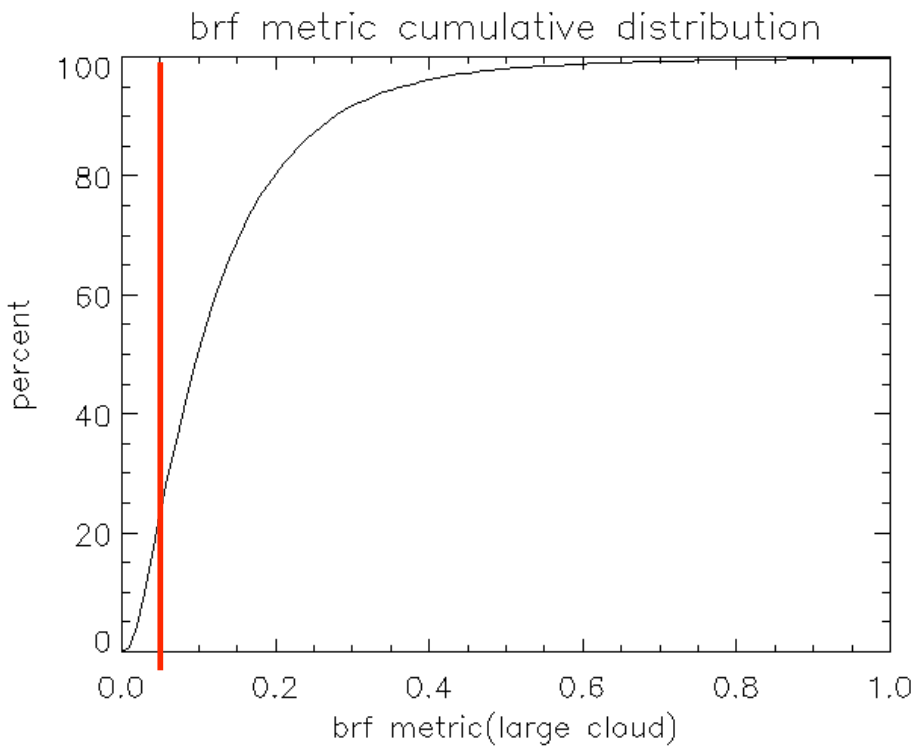
Summary to Date

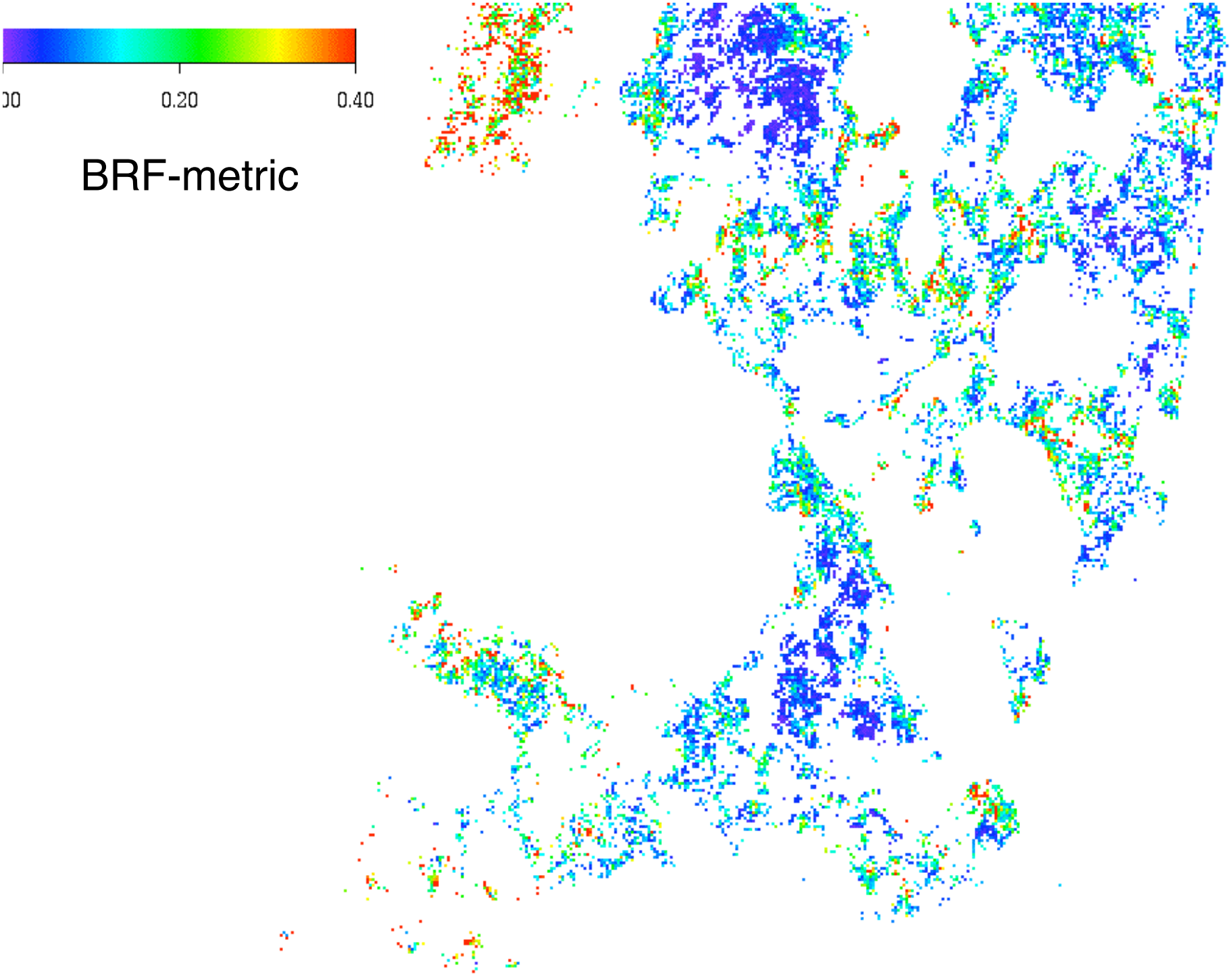
- To my surprise and Steve's relief, ~70 to 80% of MODIS retrieved optical depths for water clouds had relative errors of less than 20% (Answer b!). *The quality looks worse for the BRF-metric.*

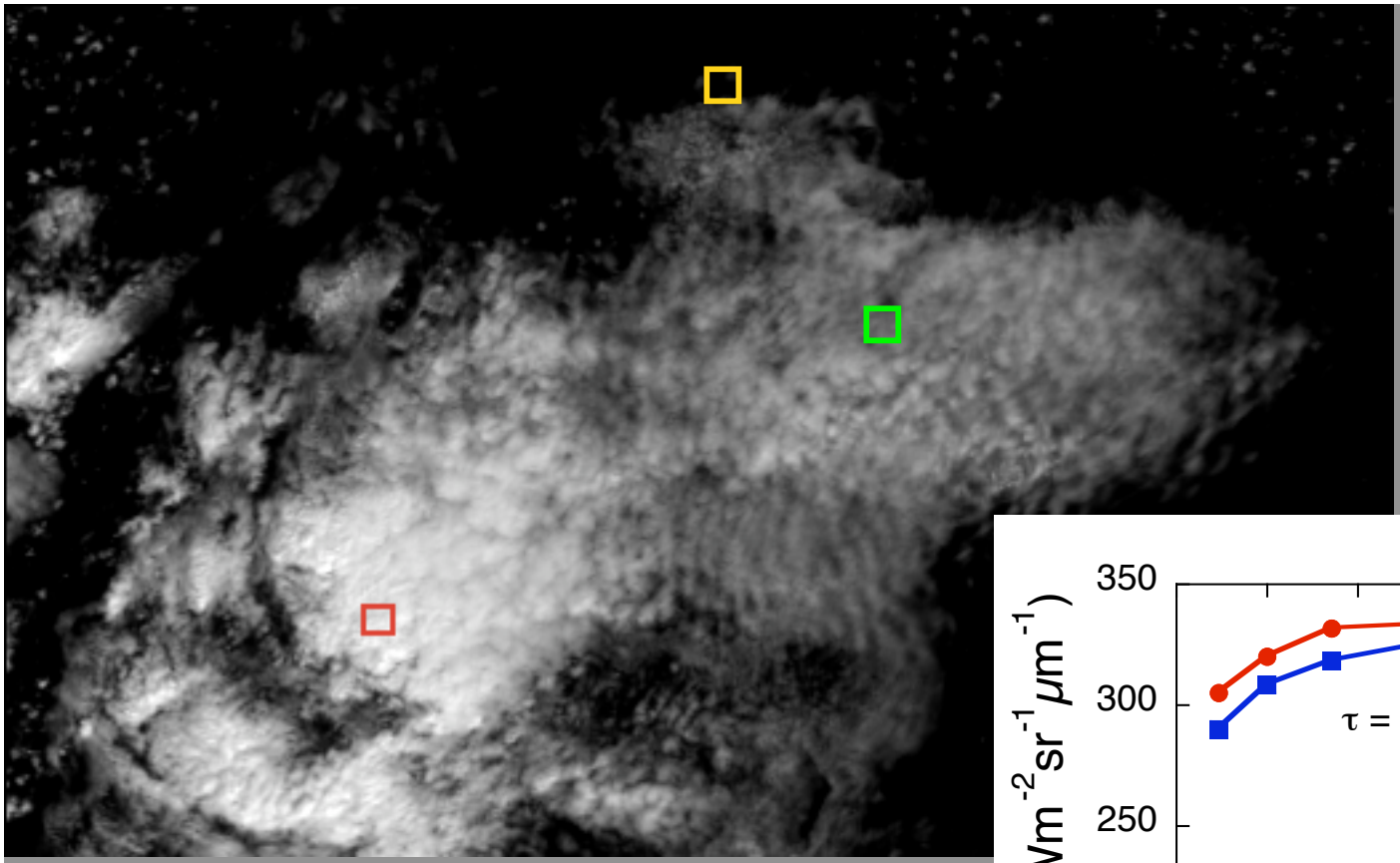
- Higher horizontal heterogeneity led to an increase in optical depth uncertainty, but horizontally homogeneous clouds had a large range of uncertainty in optical depth… *it is not just 3D effects that contribute uncertainty to the retrieval.*

Path 48 BRF metric



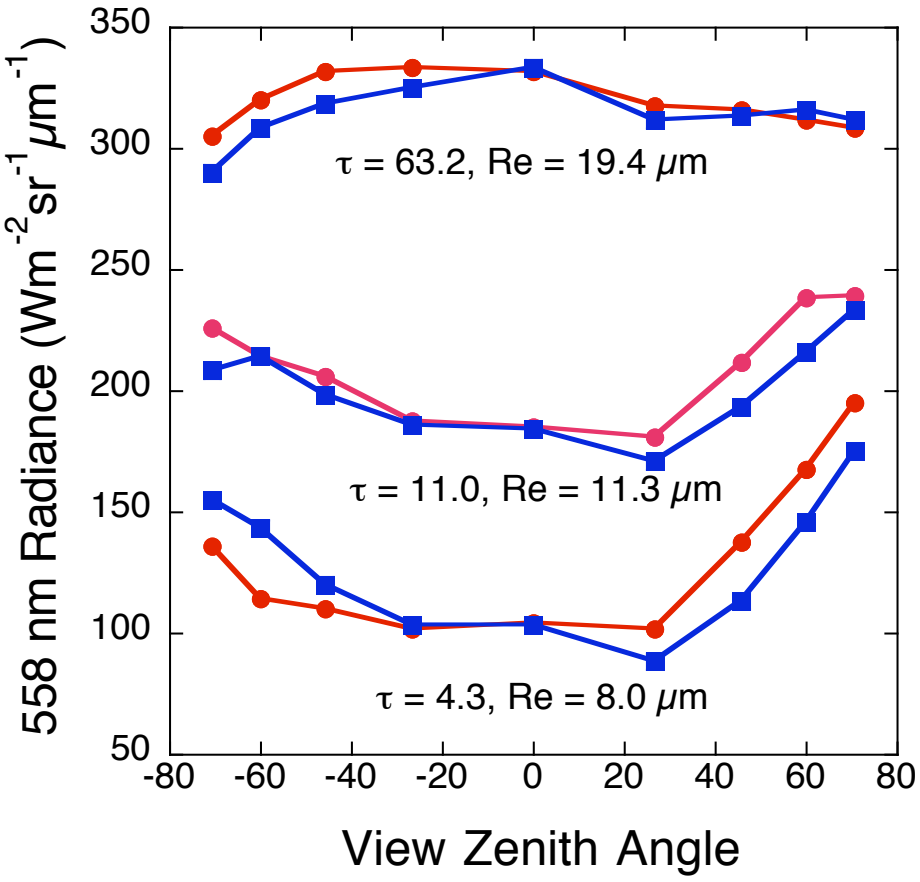


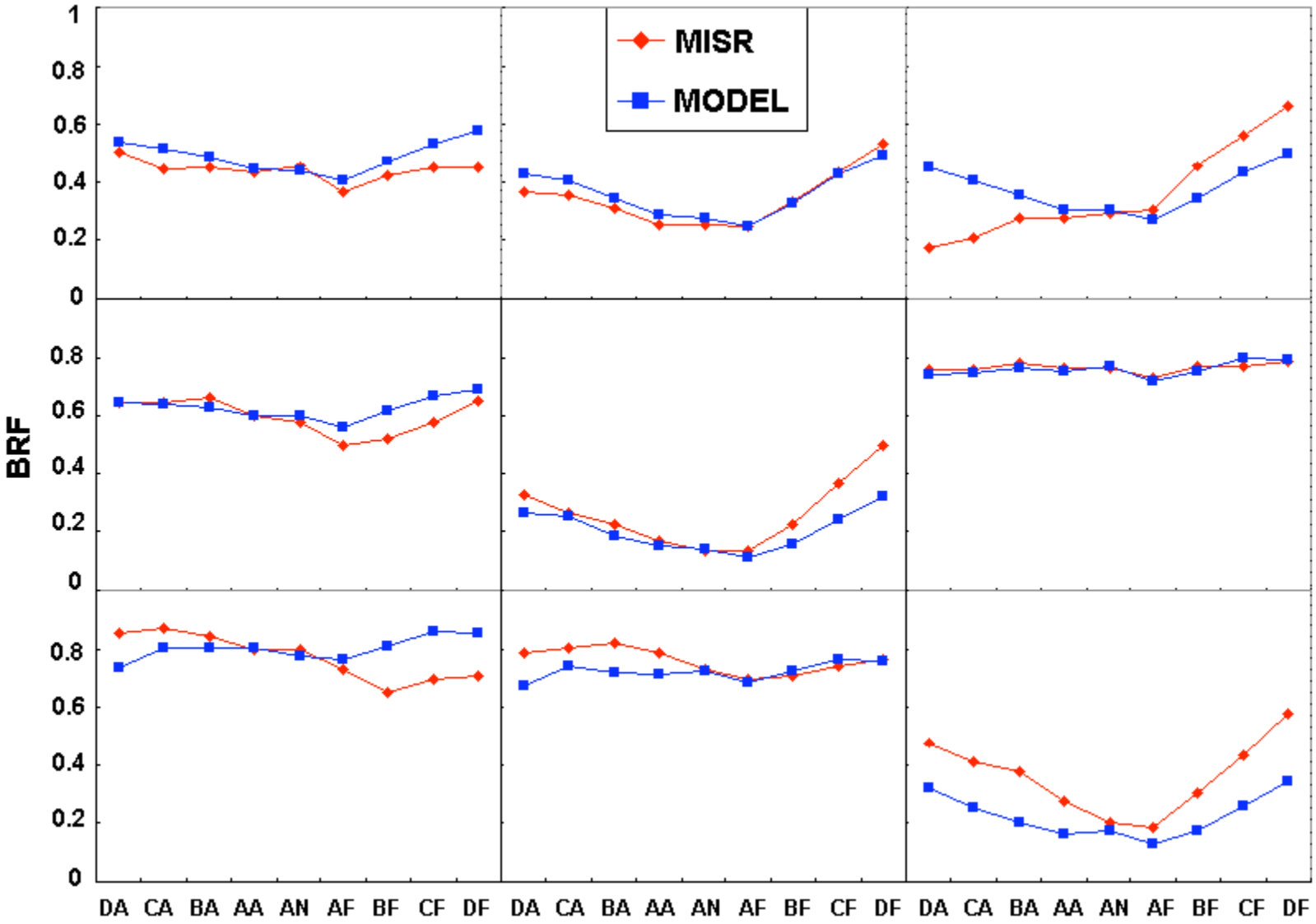

00
0.20
0.40
BRF-metric

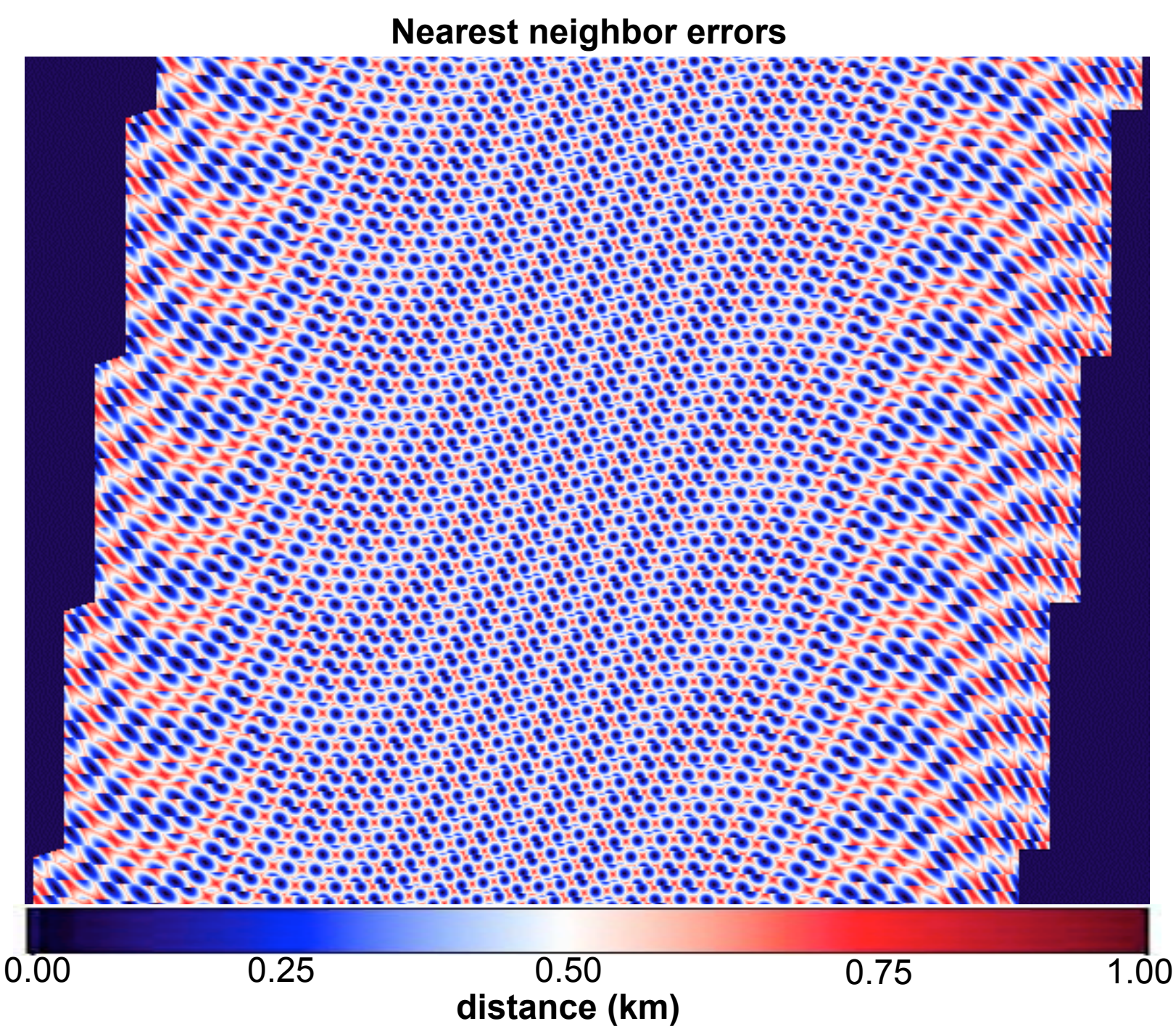


October 29, 2003
25.7°N, 60.4°W

MISR
1-D RTM

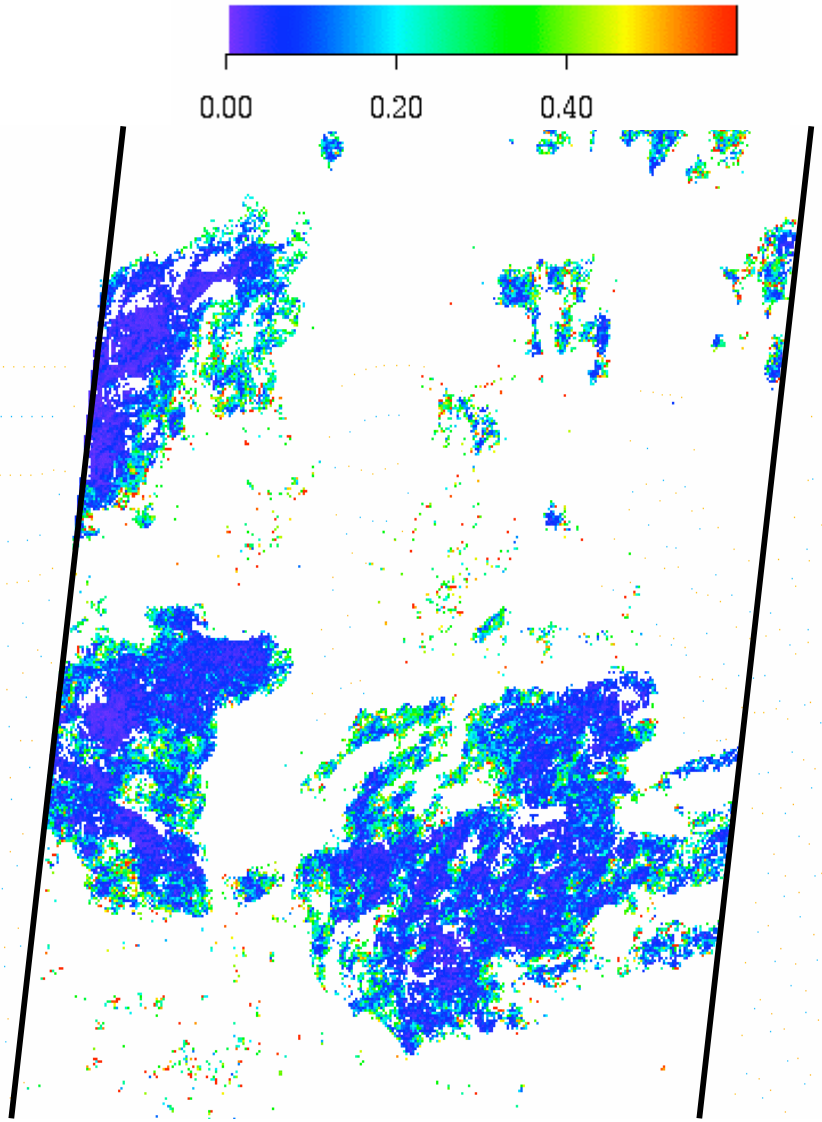


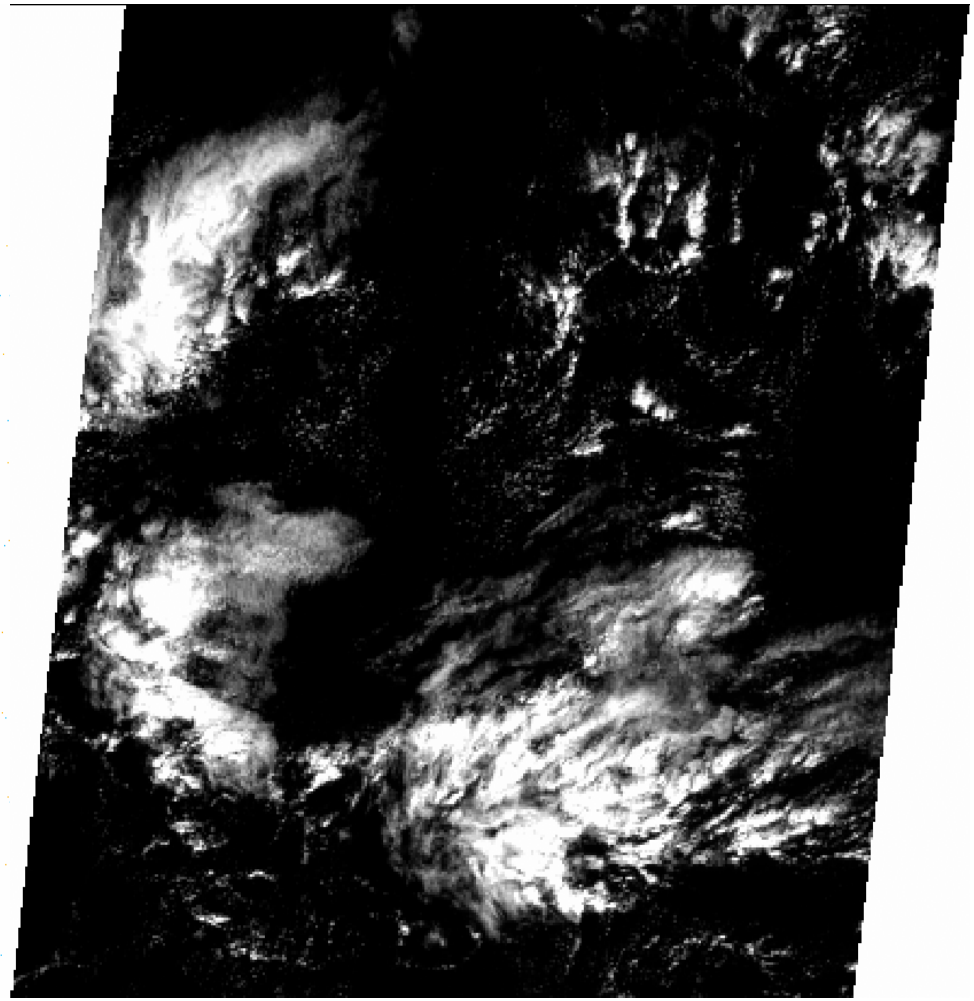

MISR
MODEL
BRF
1
0.8
0.6
0.4
0.2
0
DA CA BA AA AN AF BF CF DF

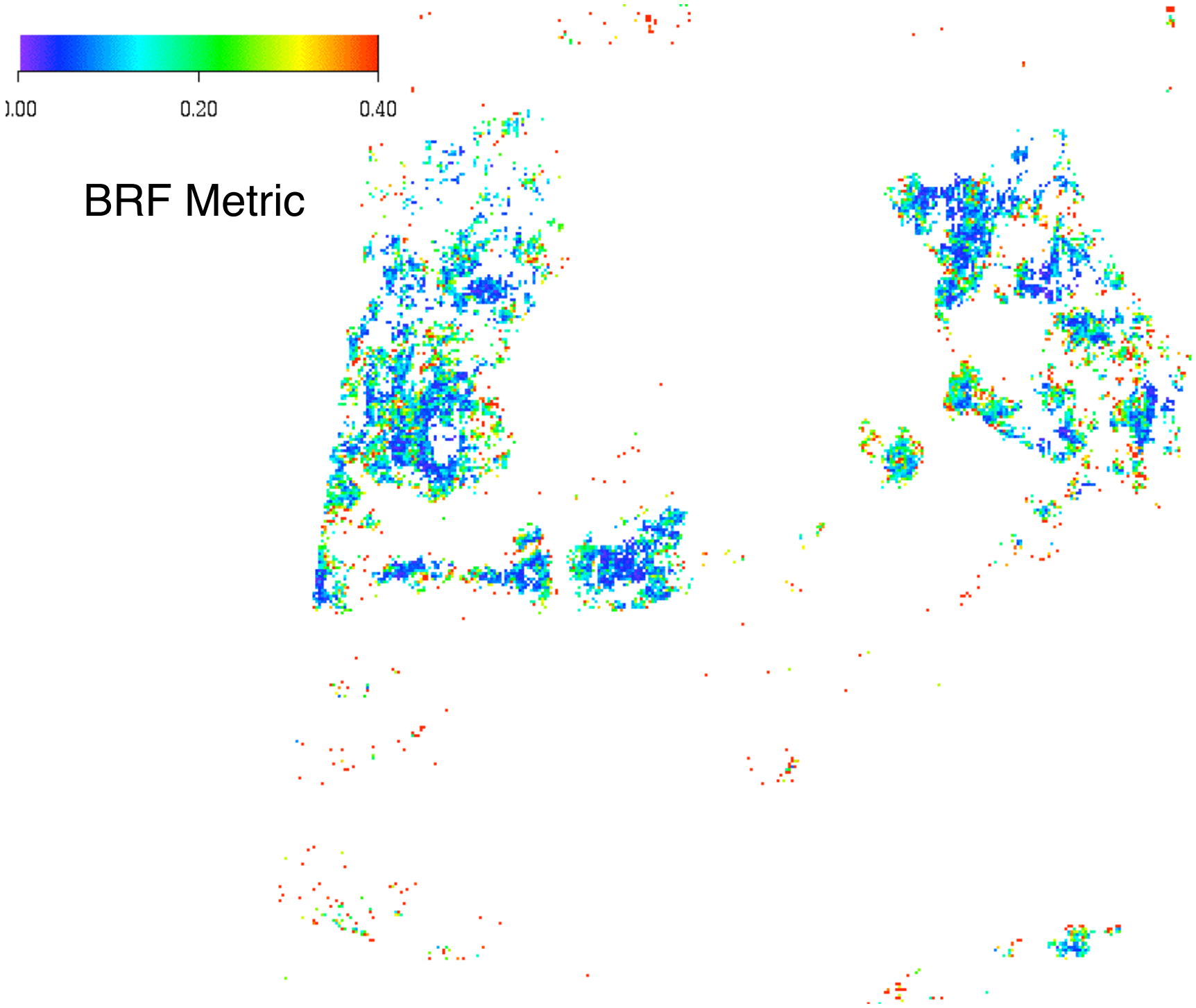

Nearest neighbor errors
0.00
0.25
0.50
0.75
1.00
distance (km)

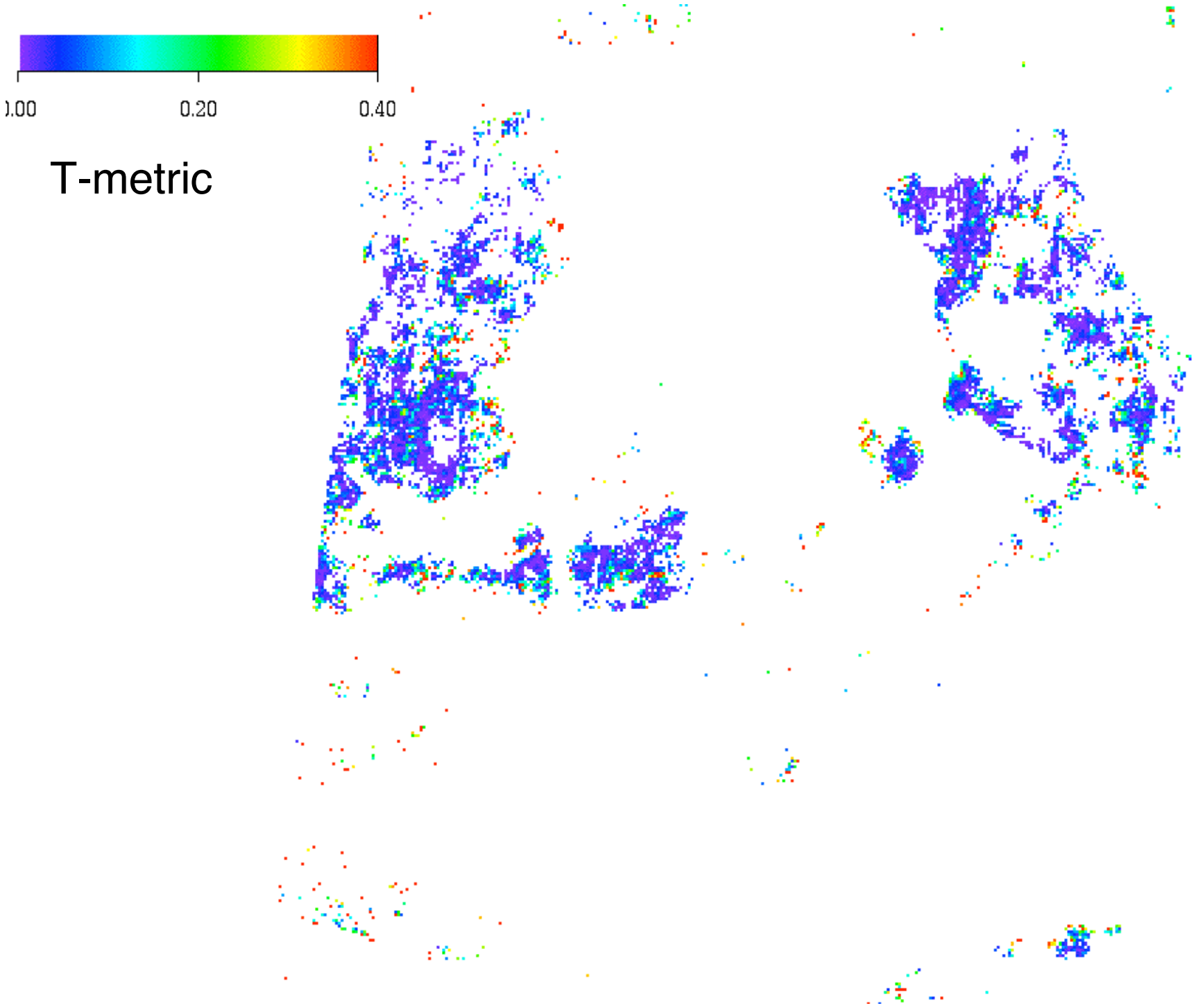
$$Difference = \frac{\sum_{i=backward\ camera}^{forward\ camera} \frac{|MISR(i) - MODEL(i)|}{MISR(i)}}{number\ of\ cameras}$$

October 29, 2003
25.7°N, 60.4°W

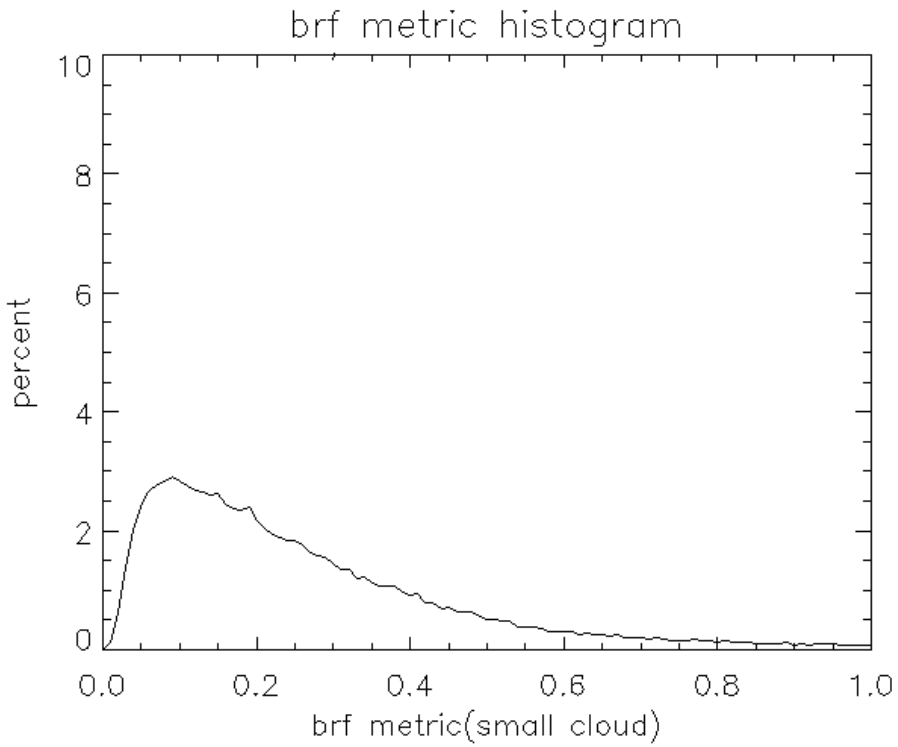


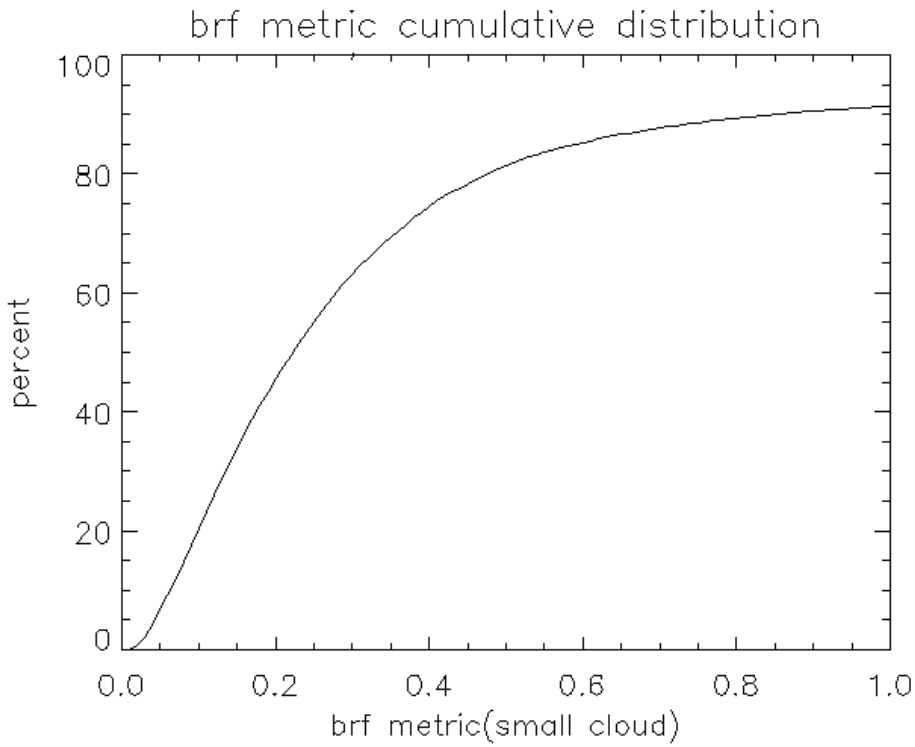



).00
0.20
0.40
BRF Metric


.00
0.20
0.40
T-metric

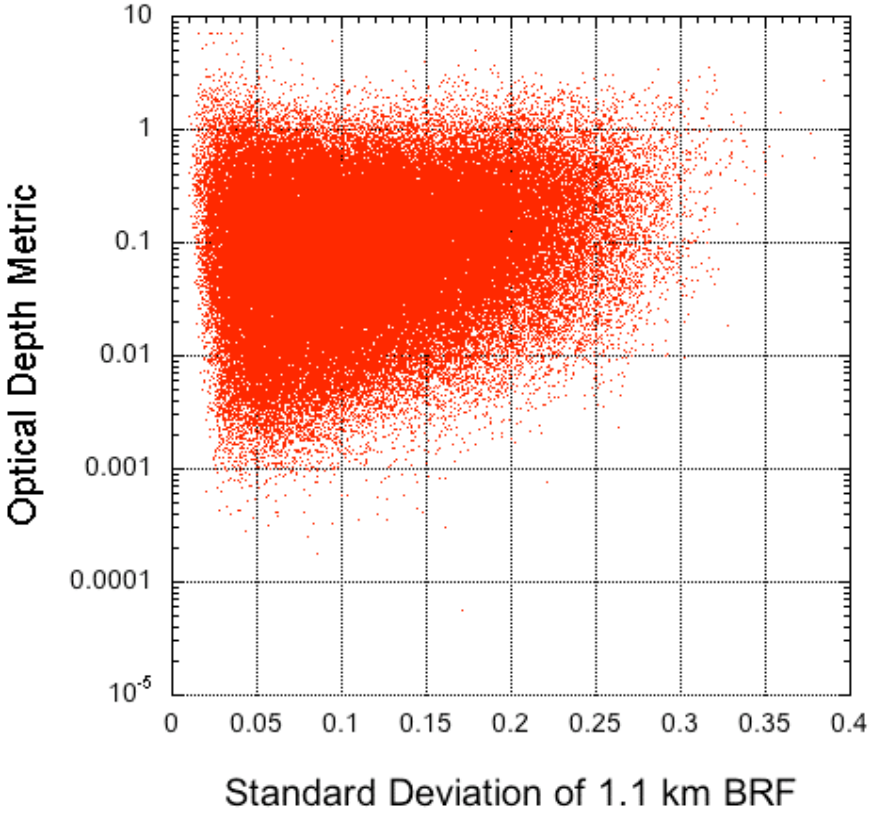
Path 233 BRF metric



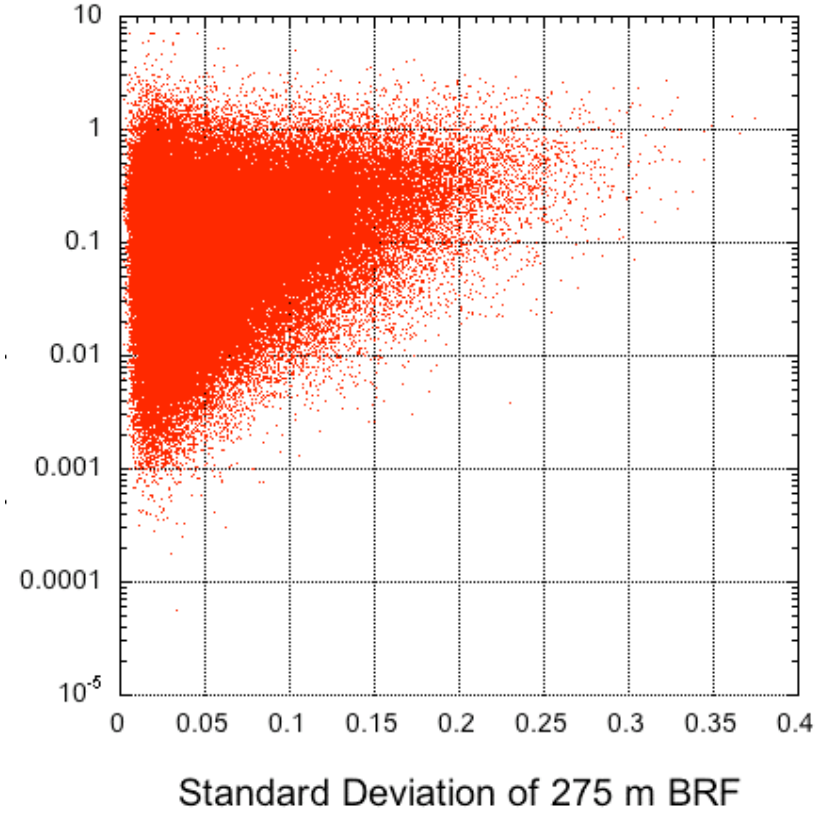


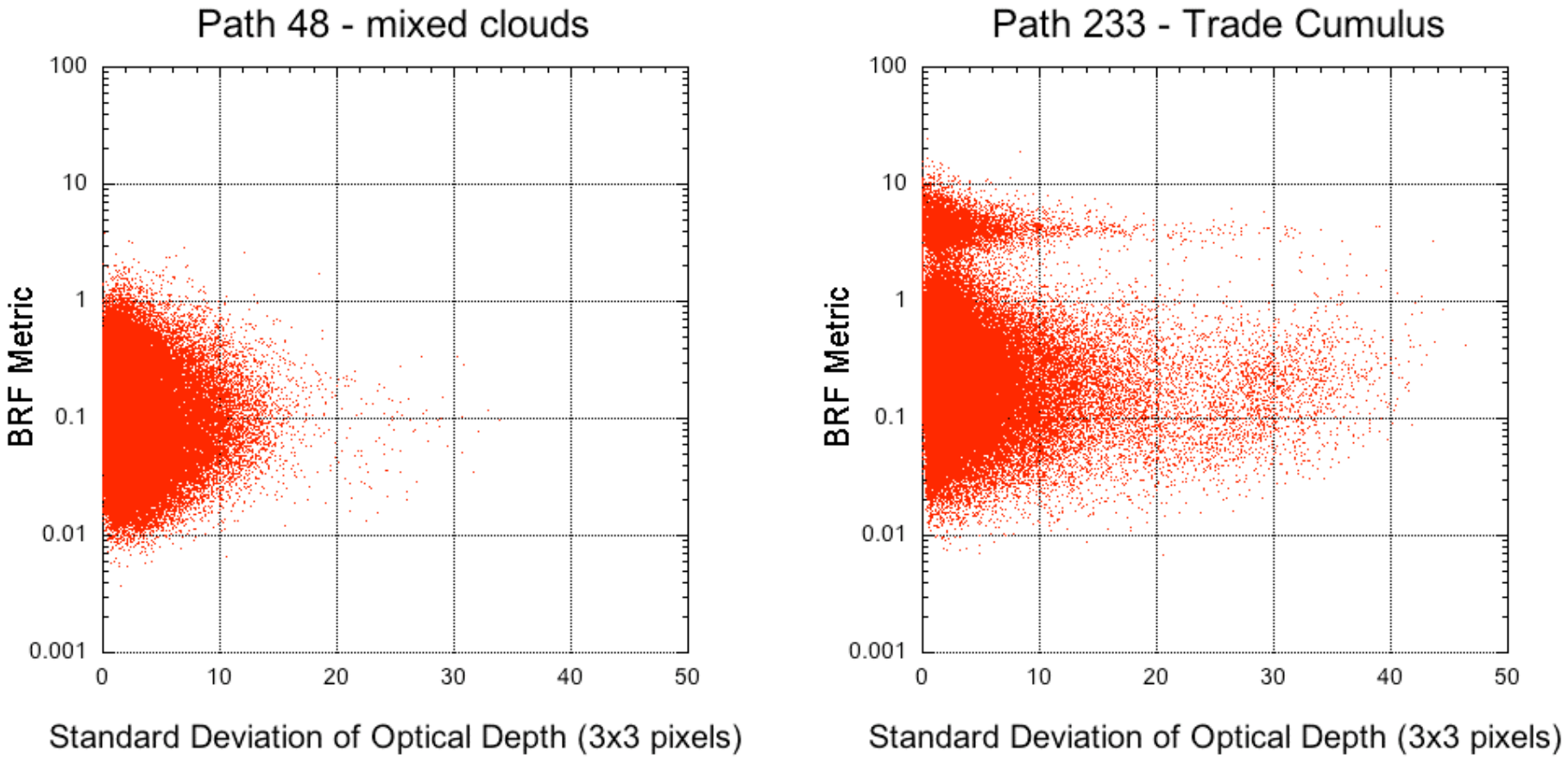
Path 233 Trade Cumulus

7.7 km x 7.7 km



1.1 km x 1.1 km




Path 48 - mixed clouds
BRF Metric
100
10
1
0.1
0.01
0.001
0
10
20
30
40
50
Standard Deviation of Optical Depth (3x3 pixels)
Path 233 - Trade Cumulus
BRF Metric
100
10
1
0.1
0.01
0.001
0
10
20
30
40
50
Standard Deviation of Optical Depth (3x3 pixels)

Optical Thickness Retrieval

(collection 5 preliminary)